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**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

In re Application of Sergei Tanygin

Serial No.: Not yet assigned Group Art Unit:

Filed: Herewith Examiner:

For: **METHOD AND APPARATUS FOR CREATING ELEMENTS AND SYSTEMS FOR DESCRIPTION OF POSITION AND MOTION OF BODIES IN THREE-DIMENSIONAL SPACE TO SUPPORT ORBITAL MANEUVER ANALYSIS**

Assistant Commissioner for Patents
Box PATENT APPLICATION
Washington, D.C. 20231

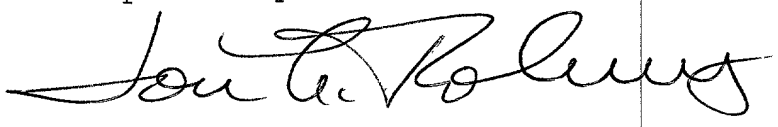
Dear Sir:

Enclosed please find the following:

1. Specification, abstract and claims (6 independent, 16 dependent, 22 total)(18 pages);
2. Informal drawings (13 figures, 7 sheets);
3. Declaration and Power of Attorney;
4. Assignment with Recordation Sheet;
5. Verified Statement Claiming Small Entity Status - Independent Inventor;
6. Verified Statement Claiming Small Entity Status - Small Business Concern;
7. One check in the amount of $520.00 ($345.00 to cover the filing fee and $40.00 to record the assignment, plus $117.00 for excess independent claims and $18.00 for excess claims); and,
8. Certificate of Express mailing.

The Commissioner is hereby authorized to charge any fee deficiency, or credit any overpayment, to Deposit Account No. 18-1579. The Commissioner is also authorized to charge Deposit Account No. 18-1579 for any future fees connected in any way to this application. Two copies of this letter are enclosed.

Respectfully submitted,



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January 26, 2000 Atty. Docket No. 2493-026

CERTIFICATE OF EXPRESS MAILING

Express Mail Mailing Label Number EL528294895US

Date of Deposit: January 26, 2000

I hereby certify that the patent application of Sergei Tanygin for a **METHOD AND APPARATUS FOR CREATING ELEMENTS AND SYSTEMS FOR DESCRIPTION OF POSITION AND MOTION OF BODIES IN THREE-DIMENSIONAL SPACE TO SUPPORT ORBITAL MANEUVER ANALYSIS** including the specification, abstract, and claims (6 independent, 16 dependent, 22 total)(18 pages); informal drawings (13 figures, 7 sheets); declaration and power of attorney; an assignment together with a recordation cover sheet; Verified Statement Claiming Small Entity Status - Small Business Concern; Verified Statement Claiming Small Entity status - Independent Inventor; and a check in the amount of $520.00 ($345.00 to cover the filing fee and $40.00 to record the assignment, plus $117.00 for excess independent claims and $18.00 for excess claims), are being deposited with the United States Postal Service for "Express Mail" service under 37 C.F.R. § 1.10 on the date indicated above and are addressed to the Assistant Commissioner for Patents, Box Patent Application, Washington, D.C. 20231.

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January 26, 2000 Atty. Docket No. 2493-026

PTO/SB/10(11-90)

| VERIFIED STATEMENT CLAIMING SMALL ENTITY STATUS (37 CFR 1.9(f) & 1.27(c))--SMALL BUSINESS CONCERN | Docket Number 2493-026 |
|---|---|

Applicant or Patentee: Sergei Tanygin
Serial or Patent No.: Not Yet Issued
Filed or Issued: Herewith
Title: **METHOD AND APPARATUS FOR CREATING ELEMENTS AND SYSTEMS FOR DESCRIPTION OF POSITION AND MOTION OF BODIES IN THREE-DIMENSIONAL SPACE TO SUPPORT ORBITAL MANEUVER ANALYSIS**

I hereby declare that I am:
☐ the owner of the small business concern identified below:
☒ an official of the small business concern empowered to act on behalf of the concern identified below:

NAME OF SMALL BUSINESS CONCERN Analytical Graphics, Inc.
ADDRESS OF SMALL BUSINESS CONCERN 325 Technology Drive, Malvern PA. 19355

I hereby declare that the above identified small business concern qualifies as a small business concern as defined in 13 CFR 121.12, and reproduced in 37 CFR 1.9(d), for purposes of paying reduced fees to the United States Patent and Trademark Office, in that the number of employees of the concern. including those of its affiliates, does not exceed 500 persons. For purposes of this statement, (1) the number of employees of the business concern is the average over the previous fiscal year of the concern of the persons employed on a full-time, part-time or temporary basis during each of the pay periods of the fiscal year, and (2) concerns are affiliates of each other when either, directly or indirectly, one concern controls or has the power to control the other, or a third party or parties controls or has the power to control both.

I hereby declare that rights under contract or law have been conveyed to and remain with the small business concern identified above with regard to the invention described in:

☒ the specification filed herewith with title as listed above.
☐ the application identified above.
☐ the patent identified above.

If the rights held by the above identified small business concern are not exclusive, each individual, concern or organization having rights in the invention must file separate verified statements averring to their status as small entities, and no rights to the invention are held by any person. other than the inventor, who would not qualify as an independent inventor under 37 CFR 1.9(c) if that person made the invention, or by any concern which would not qualify as a small business concern under 37 CFR 1.9(d), or a nonprofit organization under 37 CFR 1.9(e).

Each person, concern, or organization having any rights in the invention is listed below:

☒ no such person, concern or organization exists.
☐ each such person, concern or organization is listed below.

Separate verified statements are required from each named person, concern or organization having rights to the invention averring to their status as small entities. (37 CFR 1.27).

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlements to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate (37 CFR 1.289(b))

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

NAME OF PERSON SIGNING Paul Graziani
TITLE OF PERSON IF OTHER THAN OWNER President
ADDRESS OF PERSON SIGNING 325 Technology Drive, Malvern, PA, 19355
SIGNATURE Paul L. Graziani DATE Jan 22, 2000

| VERIFIED STATEMENT CLAIMING SMALL ENTITY STATUS (37 CFR 1.9(f) & 1.27(b))--INDEPENDENT INVENTOR | Docket Number 2493-026 |
|---|---|

Applicant or Patentee: Sergei Tanygin

Serial or Patent No.: Not Yet Issued

Filed or Issued: Herewith

Title: **METHOD AND APPARATUS FOR CREATING ELEMENTS AND SYSTEMS FOR DESCRIPTION OF POSITION AND MOTION OF BODIES IN THREE-DIMENSIONAL SPACE TO SUPPORT ORBITAL MANEUVER ANALYSIS**

As a below named inventor, I hereby declare that I qualify as an independent inventor as defined in 37 CFR 1.9(c) for purposes of paying reduced fees to the Patent and Trademark Office described in:

☒ the specification filed herewith with title as listed above.

☐ the application identified above.

☐ the patent identified above.

I have not assigned. granted, conveyed or licensed and am under no obligation under convey or law to assign, grant, convey or license. any rights in the invention to any person who would not qualify as an independent inventor under 37 CFR 1.9(c) if that had made the invention, or to any concern which would not qualify as a business concern under 37 CFR 1.9(d) or a nonprofit organization under 37 CFR 1.9(c).

Each person, concern or organization to which I have assigned, granted, conveyed, or licensed or am under an obligation under contract or law to assign, grant, convey, or license any rights in the invention is listed below:

☐ No such person, concern, or organization exists.

☒ Each such person, concern or organization is listed below.

**Analytical Graphics, Inc.**

Separate verified statements are required from each named person, concern or organization having rights to the invention averring to their status as small entities. (37 CFR 1.27)

I acknowledge the duty to file in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate.(37 CFR 128(b))

I hereby declare that all statements made herein of my own knowledge are true and that all statements made an information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

| Sergei Tanygin | | |
|---|---|---|
| NAME OF INVENTOR | NAME OF INVENTOR | NAME OF INVENTOR |
| Signature of inventor | Signature of inventor | Signature of inventor |
| 1-19-2000 | | |
| Date | Date | Date |

**Title of the Invention:** Method and Apparatus for Creating Elements and Systems for Description of Position and Motion of Bodies in Three-Dimensional Space to Support Orbital Maneuver Analysis

**Inventor:** Sergei Tanygin

## RELATED APPLICATIONS

This application claims priority from U.S. provisional patent application no. 60/117,183, filed January 26, 1999.

## BACKGROUND OF THE INVENTION

### 1. Field of the Invention

This invention relates to analysis of spacecraft orbits, trajectories, and maneuvers. More specifically, the invention relates to the creation of vectors, axes, points, coordinate systems and other elements, and combinations thereof, to be used in describing the position and motion of objects in space for maneuver planning.

### 2. Background of the Invention

In the planning and analysis of spacecraft maneuvers, the creation of vectors, axes, points, coordinate systems and other elements and combinations thereof is required in order to describe the position and motion of rigid bodies in three-dimensional space (e.g., spacecraft orbits, trajectories, and maneuvers).

A coordinate system can itself be moving in space. It can also be attached to one or more bodies or be a solely mathematical quantity. Movements of a coordinate system can be described via functions, data files, or user input to a computer program. When a coordinate system must be created, the relationship of the new system to a pre-existing one is defined. There are many ways to define that relationship, but all must include the

following: (1) a specification of how the origin of the new coordinate system is translated relative to the origin of the existing system, and (2) a specification of how the set of three orthogonal axes defining the orientation of the new system is rotated relative to the set of axes of the existing system.

This introduces two important coordinate concepts that are part of any coordinate system definition: (1) origin point, and (2) axes. Given a point in space (i.e., an "origin") and a set of axes oriented in space, one can create a coordinate system by combining the point and the axes.

If there is a plurality of points and axes, one can create any desired combination thereof, thus increasing the number of possible coordinate systems. Advantages of a system providing this capability include: (1) reusability of the coordinate points and axes, of which a limited amount can be used to create a great number of coordinate systems, and (2) improved accuracy where two or more coordinate systems share common points and/or axes, since shared components need only be defined once, thus minimizing the possibility of error in performing duplicative computations.

Another component useful in constructing a coordinate system is the vector. The vector relates to points and axes in a number of ways. A new point can be specified by a vector starting at a pre-defined point. A new vector can be defined on the basis of two existing points, starting and ending. A new set of orthogonal axes can be specified by using two non-parallel vectors. A new vector can be created by performing various vector operations (rotation about another vector, cross-product, negation, etc.). Thus, vectors, along with points and axes, provide useful building blocks for constructing new coordinate systems.

Existing programs require users to write new computer code whenever a new coordinate relationship is introduced. Alternatively, when a graphical user interface (GUI) is provided, the choices offered by the GUI are limited to a certain subset of the myriad possibilities, thus limiting the options available for the analyst.

Some existing programs require that all relationships of interest be hard-coded, whereas some require that only one relationship be hard-coded. For example, the Jet Propulsion Laboratory (JPL) distributes the SPICE toolkit that contains a set of functions to perform coordinate conversions. The conversions can be obtained between any two of the specified coordinate frames, with each new frame specified relative to some existing frame. Nevertheless, this is a laborious task, since the specification must be performed through a file. The JPL SPICE toolkit also lacks the ability to specify points or vectors, which are crucial building blocks for interrelating various coordinate systems.

Another existing program, the Navigator software module (a product of Analytical Graphics, Inc. of Malvern, PA), provides a GUI for constructing coordinate systems, but is limited in that it constructs coordinate axes alone. It is not capable of constructing vectors from points nor axes from vectors. Furthermore, the Navigator module cannot construct a coordinate system from a set of axes and a point. Finally, the Navigator module has no capability to account for coordinate systems that rotate with respect to each other.

Thus, what is needed is a scheme for a spacecraft maneuver analyst to specify relationships for new coordinate systems without the need to hard-code a software solution. What is also needed is a scheme for a spacecraft maneuver analyst to model orbital maneuver phenomena according to any of a myriad of possible coordinate systems without the need to hard-code a software solution.

## SUMMARY OF THE INVENTION

It is an object of the present invention to provide a scheme for a spacecraft maneuver analyst to specify relationships for new coordinate systems without the need to hard-code a software solution.

It is a further object of the present invention to provide a scheme for a spacecraft maneuver analyst to model orbital maneuver phenomena according to any of a myriad of possible coordinate systems without the need to hard-code a software solution.

It is another object of the present invention to provide a method of creating new spatial objects based on pre-existing parent objects.

It is yet another object of the present invention to provide a computer system that is adapted to create new spatial objects based on pre-existing parent objects.

It is still another object of the present invention to provide a computer program product for enabling a computer system to create new spatial objects based on pre-existing parent objects.

It is a still further object of the present invention to provide a method of creating a desired target object based on a pre-existing parent object and on information explicitly provided by a user.

It is another object of the present invention to provide a computer system that is adapted to create new spatial objects based on a pre-existing parent object and on information explicitly provided by a user.

It is a further object of the present invention to provide a computer program product for enabling a computer system to create new spatial objects based on a pre-existing parent object and on information explicitly provided by a user.

Some of the above objects are obtained, according to the present invention, by a method of creating a desired target object based on one or more pre-existing parent objects. The method includes performing a finding operation to find the target object in terms of each of the parent objects, as well as performing a building operation to obtain a combined transformation based on the parent objects. The target object is created by the combined transformation of the parent objects.

Others of the above objects are obtained by a computer system implementing this method of creating a desired target object based on one or more pre-existing parent objects. Still others of the above objects are obtained by a computer program product embodying instructions that cause a computer to implement this method of creating a desired target object based on one or more pre-existing parent objects.

Certain of the above objects are obtained, according to the present invention, by a method of creating a desired target object based on a pre-existing parent object and on information explicitly provided by a user. The method includes performing a finding operation to find the target object in terms of the parent object, using the information explicitly provided by the user, to obtain a first transformation, as well as performing a finding operation to find the parent object with respect to the target object, to obtain a second transformation. Additionally, the method includes combining the first and second transformations to create the target object.

The present invention provides a GUI and software architecture that empowers the user to create new vectors, axes, points, coordinate systems, and other elements, and combinations thereof. The explicit means of creating coordinate systems and primitives are carried out via user input, imported data from files, or any other means of supplying

numerical data to computer programs. In addition to geometrical relationships, coordinate system definitions can describe rates of change in the primitives, thus providing additional ways to create vectors.

## BRIEF DESCRIPTION OF THE DRAWINGS

**Fig. 1A** illustrates a basic functional relationship between a point and coordinate system primitives.

**Fig. 1B** illustrates a basic functional relationship between a coordinate system and coordinate system primitives.

**Fig. 1C** illustrates a basic functional relationship between a vector and coordinate system primitives.

**Fig. 1D** illustrates a basic functional relationship between a set of axes and coordinate system primitives.

**Fig. 2A** illustrates basic constructional relationships between a new point and existing coordinate system primitives.

**Fig. 2B** illustrates basic constructional relationships between a new vector and existing coordinate system primitives.

**Fig. 2C** illustrates basic constructional relationships between new axes and existing coordinate system primitives.

**Fig. 2D** illustrates basic constructional relationships between a new coordinate system and existing coordinate system primitives.

**Fig. 3** illustrates a flow chart of a typical "FindIn" call

**Fig. 4** illustrates a flow chart for the case in which an object is built from pre-existing (or previously constructed) objects.

**Fig. 5** illustrates a simple example of the invention implemented in conjunction with the Astrogator program.

**Fig. 6** illustrates further the implementation example of Fig. 5.

**Fig. 7** illustrates further the implementation example of Fig. 5.

## DETAILED DESCRIPTION OF THE INVENTION

In one embodiment, the invention relates to the creation of coordinate systems and primitives thereof in the context of a computer program for spacecraft mission analysis, such as the Astrogator module of the Satellite Tool Kit (STK) program developed by Analytical Graphics, Inc. of Malvern, Pennsylvania.

The present invention provides a GUI and software architecture that empowers the user to create new vectors, axes, points, coordinate systems, and other elements, and combinations thereof, in the following ways:

1) specifying a point explicitly relative to an existing coordinate system;

2) specifying a vector explicitly relative to an existing set of axes;

3) specifying a set of axes explicitly relative to an existing set of axes;

4) specifying a coordinate system explicitly relative to an existing coordinate system;

5) defining a point by an existing vector (i.e., the end point);

6) defining a vector by two points (i.e., start point and end point);

7) defining a vector by one or more existing vectors via vector operations (e.g., cross product);

8) defining a set of coordinate axes by two non-parallel vectors; and

9) defining a coordinate system as a combination of a point (origin) and a set of coordinate axes.

The explicit means of creating coordinate systems and primitives (items 1-4, above) are carried out via user input, imported data from files or any other means of supplying numerical data to computer programs. In addition to geometrical relationships, coordinate system definitions can describe rates of change in the primitives, thus providing additional ways to create vectors:

a. the rate of change of a vector constitutes another vector;

b. the rate of change of a point (i.e., its velocity) constitutes a vector; and

c. the rate of change of axes (rate of rotation or angular rate) constitutes a vector.

The present invention gives users the ability to introduce new coordinate primitives by both direct specification through user/file input, and by building them out of existing primitives at run-time through the interface. Coordinate primitives created by both methods can then be reused immediately as building blocks for creating more primitives. The amount of actual coding needed to create a wide range of useful primitives is reduced dramatically compared to conventional systems, creation may be performed at run-time, and manageability of the code is improved since correction made to one of the primitives is automatically inherited by all primitives using this block.

While the above description focuses on the use of the invention to create coordinate systems and primitives thereof, it is not intended that the invention be limited to this application. An aspect of the invention is its flexibility in allowing the user to define a variety of elements and combinations thereof for describing the position and movement of bodies in three-dimensional space.

Referring to **Figs. 1A-1D**, the basic functional relationships among coordinate system primitives are represented. The function "FindIn" (represented by a double arrow

in these Figs.) is a basic function used by the invention to find the object that calls it (i.e., the point, coordinate system, vector or set of axes in the upper ellipse in each Fig.) in any appropriate existing objects (the lower ellipses).

Referring to **Fig. 1A**, a basic functional relationship is illustrated between a point and coordinate system primitives. The basic FindIn function **110** is called by a point object **120** and finds that point object **120** in existing coordinate system objects 1 through N **130**.

Referring to **Fig. 1B**, a basic functional relationship is illustrated between a coordinate system and coordinate system primitives. The basic FindIn function **110** is called by a coordinate system object **140** and finds that coordinate system object **140** in existing coordinate system objects 1 through N **130**.

Referring to **Fig. 1C**, a basic functional relationship is illustrated between a vector and coordinate system primitives. The basic FindIn function **110** is called by a vector object **150** to find that vector object **150** in existing axes objects 1 through N **160**.

Referring to **Fig. 1D**, a basic functional relationship is illustrated between a set of axes and coordinate system primitives. The basic FindIn function **110** is called by an axes object **170** to find that axes object **170** in existing axes objects 1 through N **160**.

Referring to **Figs. 2A-2D**, the basic constructional relationships among coordinate system primitives are represented. In these figures, single arrows represent links between pre-existing objects (in the lower ellipses) and the object to be constructed (in the upper ellipse). The double arrows denote required explicit input from the user via the computer program's user interface, a data file, or another source. The words and symbols in square brackets describe the operations that must be performed on the data supplied by the linked

objects. It should be noted that there must be a fundamental point and fundamental axes specified directly by the user. These must be defined independently of other objects, since they define the original coordinate system (i.e., the base of the universe). This definition by the user may be explicit, or it may be a tacit adoption of a default universe.

Referring to **Fig. 2A**, basic constructional relationships between a new point **210** and existing coordinate system primitives **214**, **218** are illustrated. In this case, an existing vector **214** is combined with an existing point **218** to define a new point **210** in space. The user provides a link to an existing (parent) coordinate system.

Referring to **Fig. 2B**, basic constructional relationships between a new vector **220** and existing coordinate system primitives **224**, **228**, **232**, **236** are illustrated. The new vector **220** may be defined by a vector operation taken on two or more existing vectors **224**, chosen from existing vectors 1 through N **224**. Alternatively, the new vector **220** may be defined by the first derivative of an existing point or vector **228**. As yet another alternative, the new vector **220** may be defined based on the difference between two existing points **232**, **236**. In each case, the user provides a link to an existing (parent) set of axes.

Referring to **Fig. 2C**, basic constructional relationships between new axes **240** and existing coordinate system primitives **244**, **248** are illustrated. In this case, two existing vectors **244**, **248** (which should be non-parallel) are aligned to define a new set of axes **240**. The user provides a link to an existing (parent) set of axes.

Referring to **Fig. 2D**, basic constructional relationships between a new coordinate system **250** and existing coordinate system primitives **254**, **258** are illustrated. In this case,

an existing point **254** and an existing set of axes **258** are assembled to define a new coordinate system **250**. The user provides a link to an existing (parent) coordinate system.

Referring to **Fig. 3**, a flow chart is shown of a FindIn call according to an embodiment of the present invention. In this case, involving explicit input, the object is first found in its parent object **310**, using the explicit information supplied by the user. Then the FindIn function is applied to the parent object **320**, and the transformations obtained are combined **330**.

Referring to **Fig. 4**, a flow chart is shown for the case in which an object is built from pre-existing (or previously constructed) objects. In this case the target object initiates the FindIn function **410** for each of its sub-objects **420**, **430**. Then the required "building" operation (e.g., refer to the square brackets in Fig. 2) is called **440** to obtain the combined transformation.

Referring to **Figs. 5-7**, a simple example is illustrated of an implementation of the invention in the Astrogator program. **Fig. 5** shows the Astrogator Component Browser, in which an available coordinate system (User_Defined) has been selected and "cloned" (i.e., copied). A dialog box called the Astrogator Component Editor allows components of the copied coordinate system to be changed. For example, if the "Axes" field is selected, the selection window shown in **Fig. 6** appears, allowing the user to choose among several alternative sets of axes. Once the new coordinate system is created, it is available in the user interface for all spacecraft mission analysis purposes, such as definition of the initial state of the spacecraft, as shown in **Fig. 7**.

The system and method of the present invention operates on a number of standard processors known in the art. UNIX processors such as the Silicon Graphics SGI

IMPACT™ and SGI 02™ each with the Reality Engine™ or the Infinite Reality™ engine; the IBM RS6000 with Evans & Sutherland Freedom graphics accelerator; the Hewlett Packard™ HP9000™ with Evans & Sutherland graphics accelerator; the Sun Microsystems SPARC™ station with Evans & Sutherland Freedom graphics accelerator; the Sun Microsystems UltraSUN™ with Creator3D graphics hardware; Digital Equipment Corporation 4D50T and 4D60T processors. Microsoft Windows operating system hardware also can be used with the present invention with MS Windows, Windows95/98/2000, and WindowsNT operating systems with or without OpenGL Accelerators. Generally, all of the above systems should also have 48 MB of memory and at least 75MB of hard drive space available.

A system and method for creating elements and systems for description of position and motion of bodies in three-dimensional space to support orbital maneuver analysis has been disclosed. It will be appreciated by those skilled in the art that other variations may be possible without departing from the scope of the invention as disclosed.

**WHAT IS CLAIMED IS:**

1. A method of creating a desired target object based on one or more pre-existing parent objects, the method comprising:

performing a finding operation to find the target object in terms of each of the parent objects; and

performing a building operation to obtain a combined transformation based on the parent objects;

wherein the target object is created by the combined transformation of the parent objects.

2. The method of creating a desired target object of claim 1, wherein the target object is a point and the one or more pre-existing parent objects comprise a vector and a point.

3. The method of creating a desired target object of claim 2, wherein the building operation comprises a summation.

4. The method of creating a desired target object of claim 1, wherein the target object is a vector and the one or more pre-existing parent objects comprise plural vectors.

5. The method of creating a desired target object of claim 4, wherein the building operation comprises a vector operation.

6. The method of creating a desired target object of claim 1, wherein the target object is a vector and the one or more pre-existing parent objects are selected from the group consisting of: a single point and a single vector.

7. The method of creating a desired target object of claim 6, wherein the building operation comprises a derivative operation.

8. The method of creating a desired target object of claim 1, wherein the target object is a vector and the one or more pre-existing parent objects comprise plural points.

9. The method of creating a desired target object of claim 8, wherein the building operation comprises a difference operation.

10. The method of creating a desired target object of claim 1, wherein the target object is a set of orthogonal axes and the one or more pre-existing parent objects comprise plural vectors.

11. The method of creating a desired target object of claim 10, wherein the building operation comprises an alignment operation.

12. The method of creating a desired target object of claim 1, wherein the target object is a coordinate system and the one or more pre-existing parent objects comprise a point and a set of orthogonal axes.

13. The method of creating a desired target object of claim 12, wherein the building operation comprises an assembly operation.

14. A computer system adapted for creating a desired target object based on one or more pre-existing parent objects, the system comprising:

a processor;

a memory, addressable by the processor, including software instructions adapted to enable the computer system to perform the steps of:

performing a finding operation to find the target object in terms of each of the parent objects; and

performing a building operation to obtain a combined transformation based on the parent objects;

wherein the target object is created by the combined transformation of the parent objects.

15. The computer system of claim 14, wherein the target object is a coordinate system and the one or more pre-existing parent objects comprise a point and a set of orthogonal axes.

16. The computer system of claim 15, wherein the building operation comprises an assembly operation.

17. A computer program product for enabling a computer to create a desired target object based on one or more pre-existing parent objects, the computer program product comprising:

software instructions for enabling the computer to perform predetermined operations, and

a computer readable medium embodying the software instructions;

the predetermined operations including the steps of:

performing a finding operation to find the target object in terms of each of the parent objects; and

performing a building operation to obtain a combined transformation based on the parent objects;

wherein the target object is created by the combined transformation of the parent objects.

18. The computer program product of claim 17, wherein the target object is a coordinate system and the one or more pre-existing parent objects comprise a point and a set of orthogonal axes.

19. The computer program product of claim 18, wherein the building operation comprises an assembly operation.

20. A method of creating a desired target object based on a pre-existing parent object and on information explicitly provided by a user, the method comprising:

performing a finding operation to find the target object in terms of the parent object, using the information explicitly provided by the user, to obtain a first transformation;

performing a finding operation to find the parent object with respect to the target object, to obtain a second transformation; and

combining the first and second transformations to create the target object.

21. A computer system adapted for creating a desired target object based on a pre-existing parent object and on information explicitly input by a user, the system comprising:

a processor;

a memory, addressable by the processor, including software instructions adapted to enable the computer system to perform the steps of:

performing a finding operation to find the target object in terms of the parent object, using the information explicitly provided by the user, to obtain a first transformation;

performing a finding operation to find the parent object with respect to the target object, to obtain a second transformation; and

combining the first and second transformations to create the target object.

22. A computer program product for enabling a computer to create a desired target object based on a pre-existing parent object and on information explicitly input by a user, the computer program product comprising:

software instructions for enabling the computer to perform predetermined operations, and

a computer readable medium embodying the software instructions;

the predetermined operations including the steps of:

performing a finding operation to find the target object in terms of the parent object, using the information explicitly provided by the user, to obtain a first transformation;

performing a finding operation to find the parent object with respect to the target object, to obtain a second transformation; and

combining the first and second transformations to create the target object.

## ABSTRACT OF THE DISCLOSURE

The present invention provides a graphical user interface and software architecture that empowers the user to create new vectors, axes, points, coordinate systems, and other elements, and combinations thereof. The explicit means of creating coordinate systems and primitives are carried out via user input, imported data from files, or any other means of supplying numerical data to computer programs. In addition to geometrical relationships, coordinate system definitions can describe rates of change in the primitives, thus providing additional ways to create vectors.

FIG. 1A

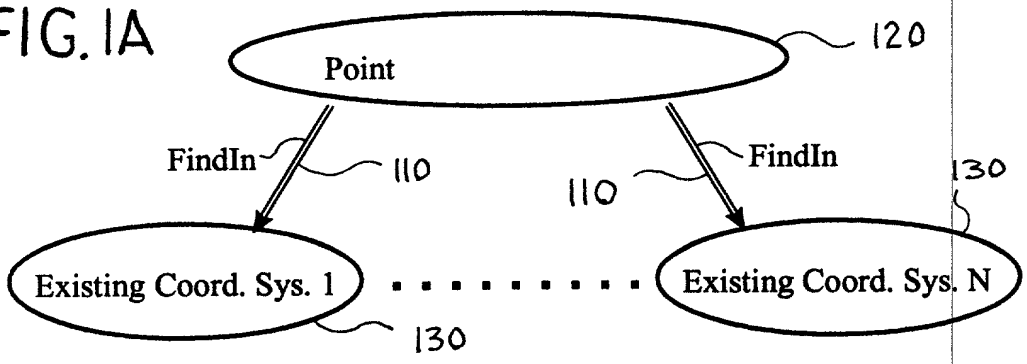

Point
120
FindIn
110
110
FindIn
130
Existing Coord. Sys. 1
Existing Coord. Sys. N
130

FIG. 1C

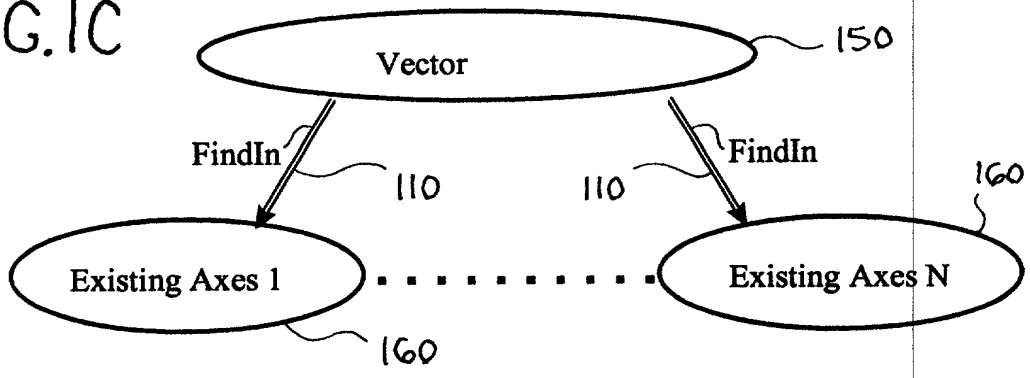

Vector
150
FindIn
110
110
FindIn
160
Existing Axes 1
Existing Axes N
160

FIG. 1B

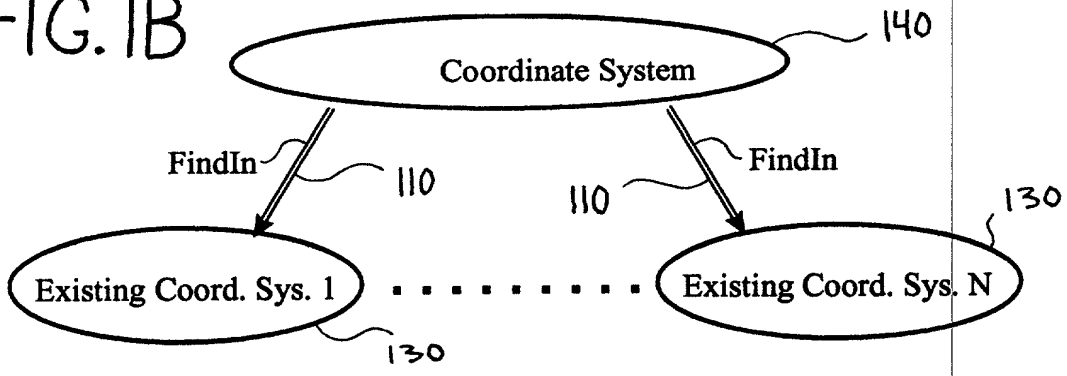
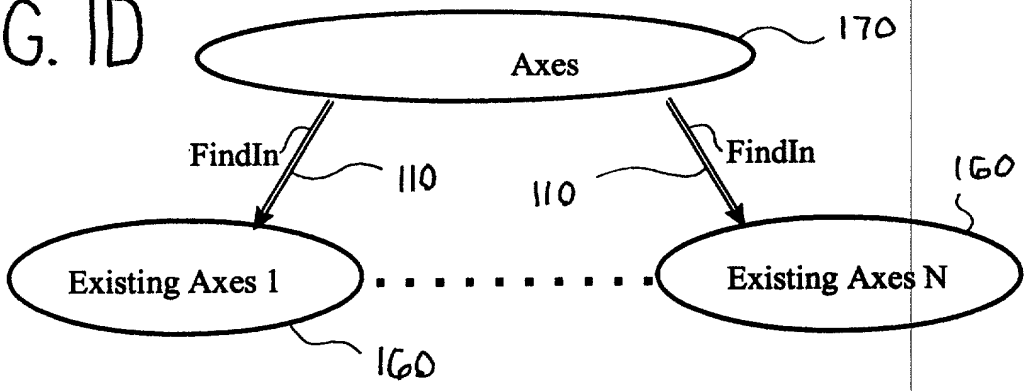

Coordinate System
140
FindIn
110
FindIn
110
130
Existing Coord. Sys. 1
Existing Coord. Sys. N
130

FIG. 1D


Axes
170
FindIn
110
FindIn
110
160
Existing Axes 1
Existing Axes N
160

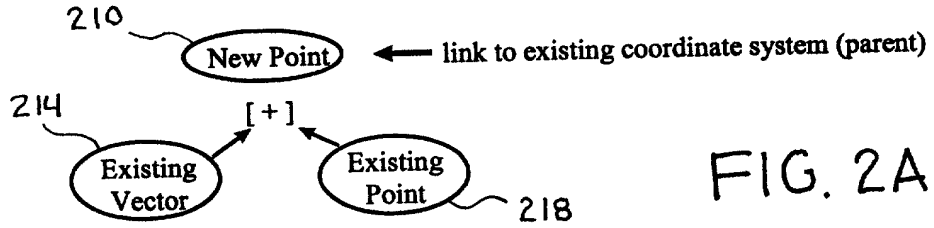



FIG. 2A

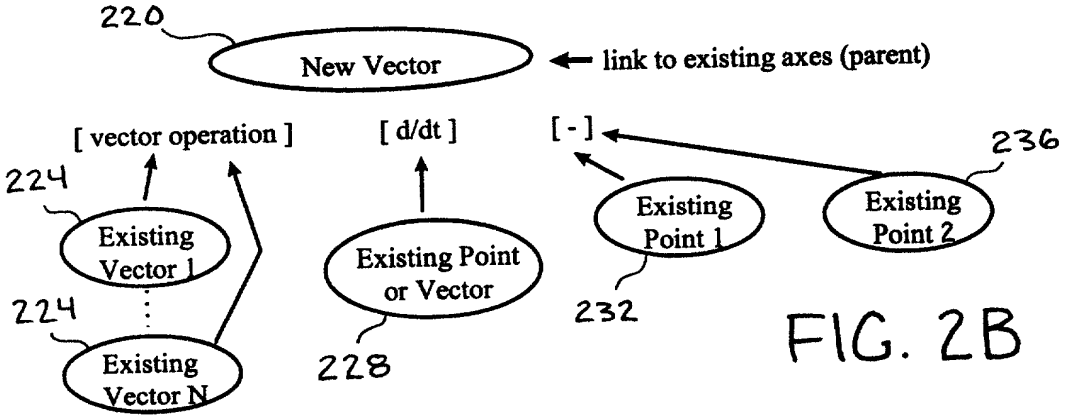



FIG. 2B

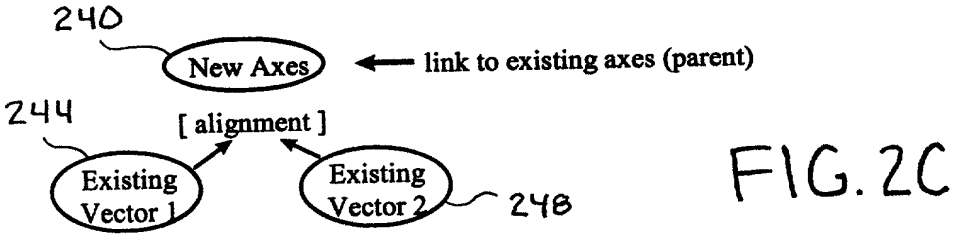



FIG. 2C

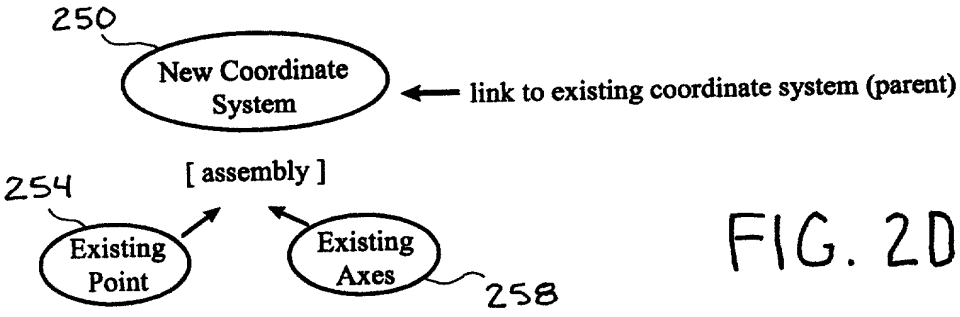



FIG. 2D

Fig. 3

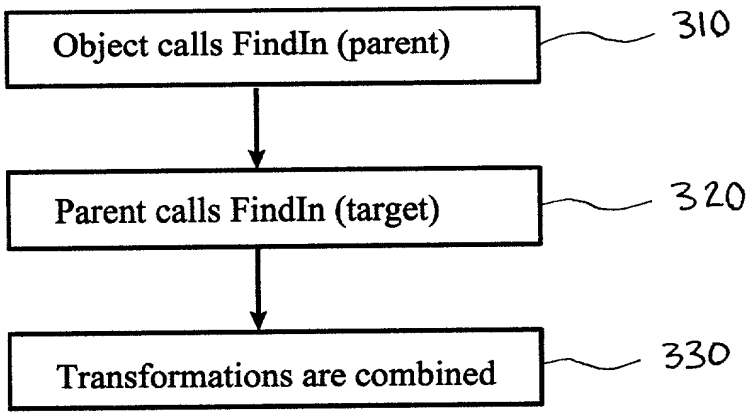

Object calls FindIn (parent)
310
Parent calls FindIn (target)
320
Transformations are combined
330

Fig. 4

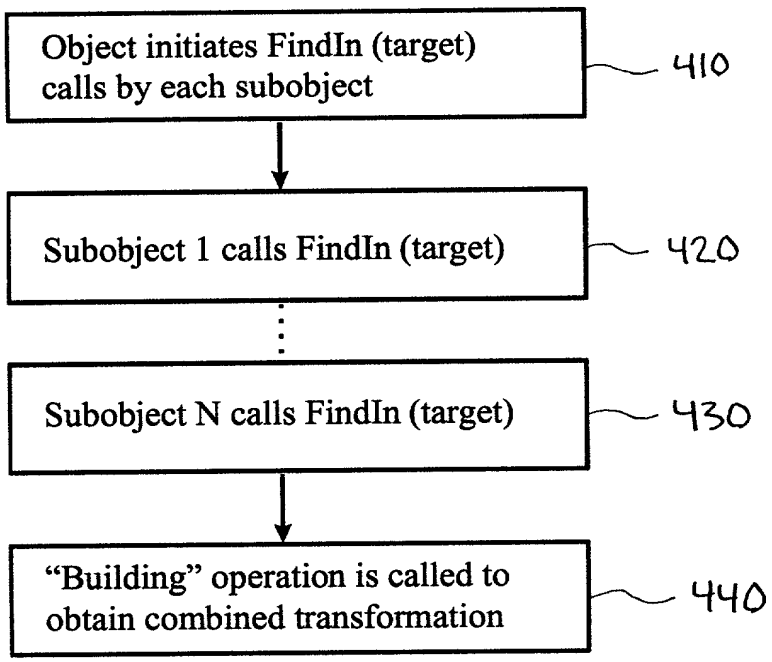

Object initiates FindIn (target) calls by each subobject
410
Subobject 1 calls FindIn (target)
420
Subobject N calls FindIn (target)
430
"Building" operation is called to obtain combined transformation
440

**Fig. 5**

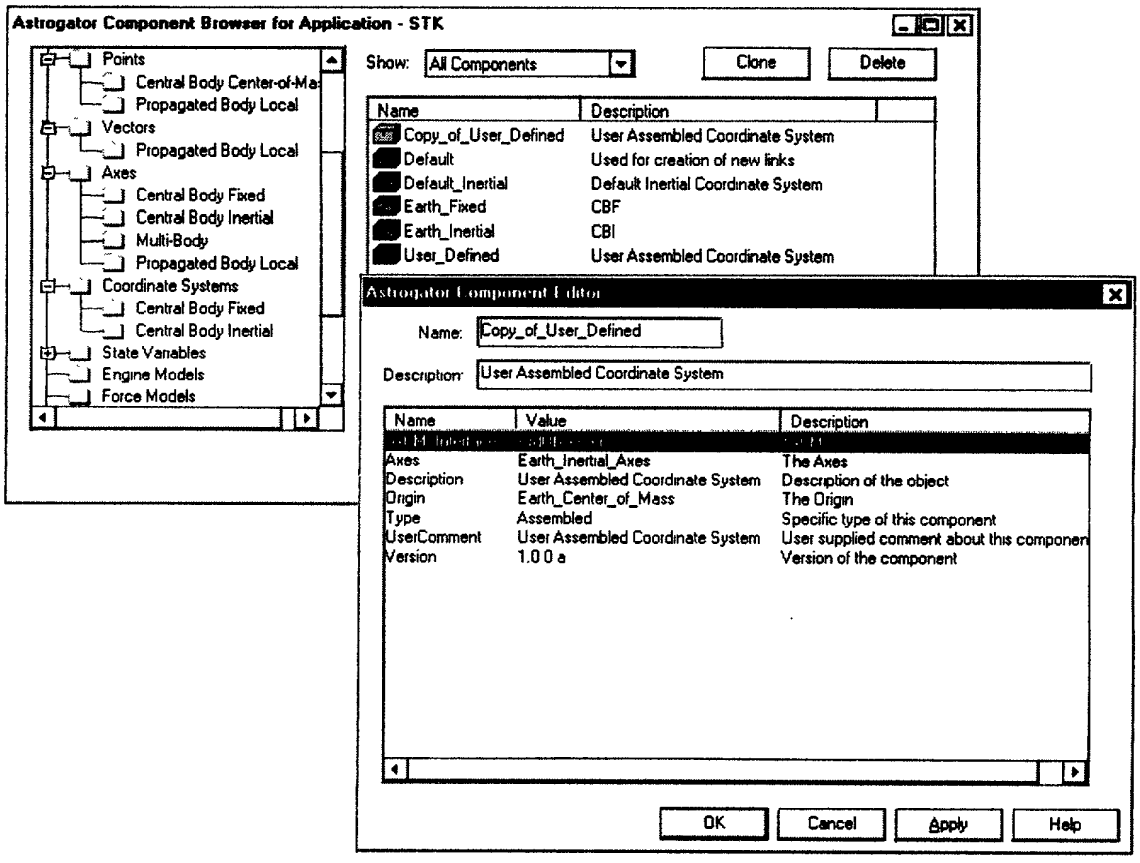

Astrogator Component Browser for Application - STK
Points
Central Body Center-of-Ma
Propagated Body Local
Vectors
Propagated Body Local
Axes
Central Body Fixed
Central Body Inertial
Multi-Body
Propagated Body Local
Coordinate Systems
Central Body Fixed
Central Body Inertial
State Variables
Engine Models
Force Models
Show: All Components
Clone
Delete
Name
Description
Copy_of_User_Defined
User Assembled Coordinate System
Default
Used for creation of new links
Default_Inertial
Default Inertial Coordinate System
Earth_Fixed
CBF
Earth_Inertial
CBI
User_Defined
User Assembled Coordinate System
Astrogator Component Editor
Name: Copy_of_User_Defined
Description: User Assembled Coordinate System
Name
Value
Description
Axes
Earth_Inertial_Axes
The Axes
Description
User Assembled Coordinate System
Description of the object
Origin
Earth_Center_of_Mass
The Origin
Type
Assembled
Specific type of this component
UserComment
User Assembled Coordinate System
User supplied comment about this componen
Version
1.0.0.a
Version of the component
OK
Cancel
Apply
Help

**Fig. 6**

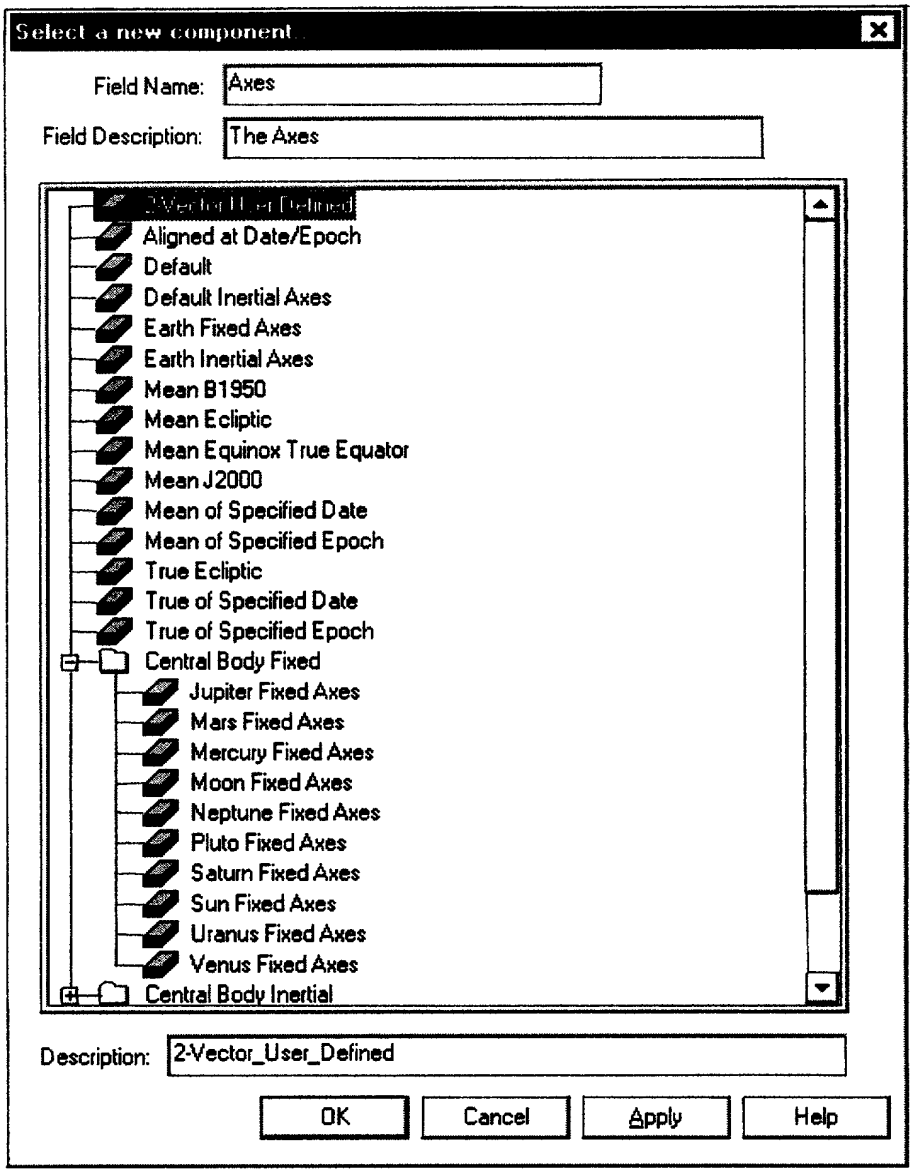
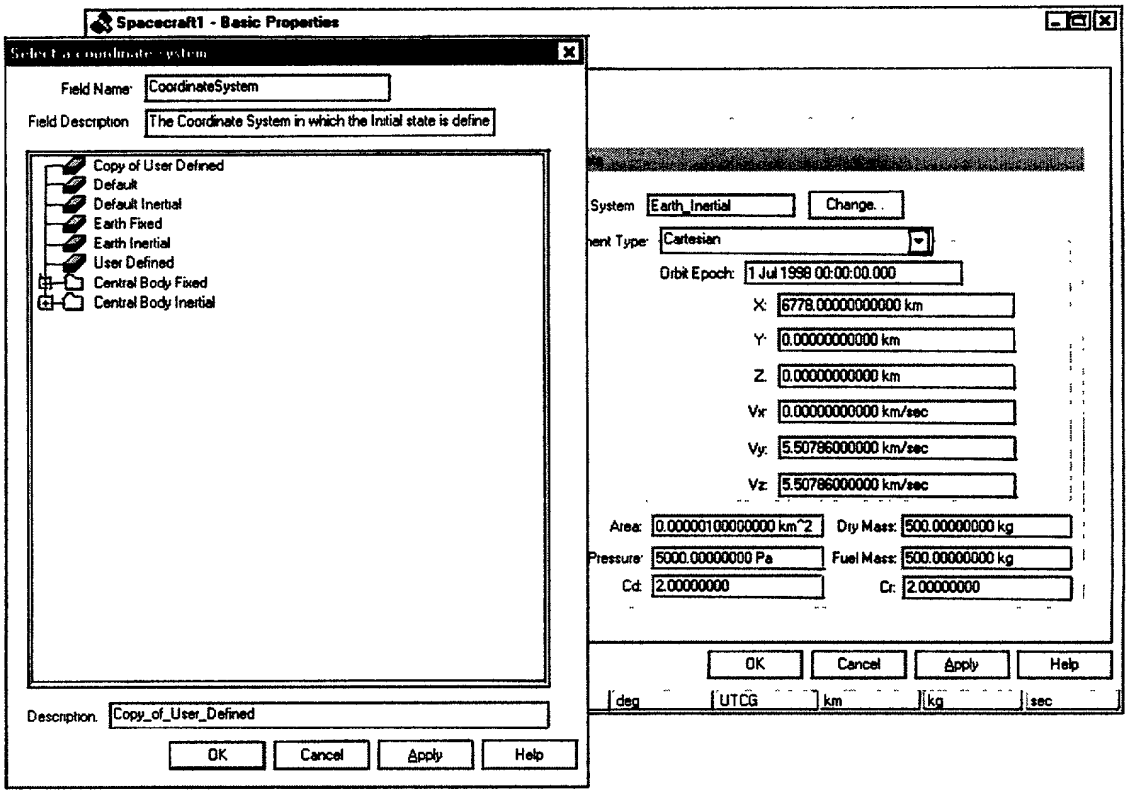

Select a new component
Field Name:
Axes
Field Description:
The Axes
2Vector User Defined
Aligned at Date/Epoch
Default
Default Inertial Axes
Earth Fixed Axes
Earth Inertial Axes
Mean B1950
Mean Ecliptic
Mean Equinox True Equator
Mean J2000
Mean of Specified Date
Mean of Specified Epoch
True Ecliptic
True of Specified Date
True of Specified Epoch
Central Body Fixed
Jupiter Fixed Axes
Mars Fixed Axes
Mercury Fixed Axes
Moon Fixed Axes
Neptune Fixed Axes
Pluto Fixed Axes
Saturn Fixed Axes
Sun Fixed Axes
Uranus Fixed Axes
Venus Fixed Axes
Central Body Inertial
Description:
2-Vector_User_Defined
OK
Cancel
Apply
Help

**Fig. 7**


Spacecraft1 - Basic Properties
Field Name: CoordinateSystem
Field Description: The Coordinate System in which the Initial state is define
Copy of User Defined
Default
Default Inertial
Earth Fixed
Earth Inertial
User Defined
Central Body Fixed
Central Body Inertial
Description: Copy_of_User_Defined
OK
Cancel
Apply
Help
System: Earth_Inertial
Change...
Cartesian
Orbit Epoch: 1 Jul 1998 00:00:00.000
X: 6778.00000000000 km
Y: 0.00000000000 km
Z: 0.00000000000 km
Vx: 0.00000000000 km/sec
Vy: 5.50786000000 km/sec
Vz: 5.50786000000 km/sec
Area: 0.00000100000000 km^2
Dry Mass: 500.00000000 kg
Pressure: 5000.00000000 Pa
Fuel Mass: 500.00000000 kg
Cd: 2.00000000
Cr: 2.00000000
OK
Cancel
Apply
Help
deg
UTCG
km
kg
sec

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

In re Application of: Sergei Tanygin

Serial No.: Not Yet Assigned — Group Art Unit: Not Yet Assigned

Filed: Herewith — Examiner: Not Yet Assigned

FOR: **METHOD AND APPARATUS FOR CREATING ELEMENTS AND SYSTEMS FOR DESCRIPTION OF POSITION AND MOTION OF BODIES IN THREE-DIMENSIONAL SPACE TO SUPPORT ORBITAL MANEUVER ANALYSIS**

## DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION

As below inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, sole and first inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled **METHOD AND APPARATUS FOR CREATING ELEMENTS AND SYSTEMS FOR DESCRIPTION OF POSITION AND MOTION OF BODIES IN THREE-DIMENSIONAL SPACE TO SUPPORT ORBITAL MANEUVER ANALYSIS**, the specification of which is attached hereto.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, § 1.56(a).

I hereby claim the benefit under 35 U.S.C. § 119(e) of United States provisional application no. 60/117,183, filed January 26, 1999.

I hereby appoint the following attorney(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

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I declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements are made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full name of inventor Sergei Tanygin

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